AD-753 349

EFFECTS OF VERTICAL WIND ON TACTICAL ROCKETS AND ARTILLERY SHELLS

Bernard F. Engebos

Army Electronics Command
White Sands Missile Range, New Mexico

November 1972

AD753349

AD

Reports Control Symbol
OSD-1366

RESEARCH AND DEVELOPMENT TECHNICAL REPORT
ECOM 5467

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Approved for public release; distribution unlimited.

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND - FORT MONMOUTH, NEW JERSEY

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UNCLASSIFIED
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(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
Atmospheric Sciences Laboratory
White Sands Missile Range, New Mexico

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
Effects of Vertical Wind on Tactical Rockets and Artillery Shells

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*
Bernard F. Engebos

6. REPORT DATE
November 1972

7a. TOTAL NO. OF PAGES
~~21~~ 19

7b. NO. OF REFS
8

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c. DA Task No. 1T061102B53A-18

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
ECOM-5467

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
U.S. Army Electronics Command
Fort Monmouth, New Jersey

13. ABSTRACT
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DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Tactical Rocket 2. Artillery Projectiles 3. Launcher Settings 4. Vertical Wind Effects 5. Trajectory Simulations 6. Wind Compensation 7. Wind Response 8. Unit Wind Effects 9. Ballistic Factors						

UNCLASSIFIED

Security Classification

Reports Control Symbol
OSD-1366

Technical Report ECOM-5467

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INTRODUCTION

In the computation of launcher angle settings for tactical rockets and/or artillery shells, one usually considers the rotation of the earth, the muzzle velocity, the horizontal wind components, the air temperature, the air density, the height of the target with respect to the launch point, the height of the launcher above sea level, and the weight of the projectile to be fired [1]. At present there is no launcher setting compensation for the vertical wind component.

This report examines the effects of the vertical wind component on projectiles and tactical rockets, and points out the possible consequences of neglecting this parameter. To accomplish this end, the Honest John (M50) tactical rocket and the 155 millimeter howitzer were selected as typical weapons. Other weapons yield similar results. All results in this report are accomplished by trajectory simulations and assume sea level as both launch and impact elevation.

DISCUSSION

The Honest John (M50) tactical rocket with the "heavy" warhead configuration is a single-stage unguided rocket with a 3.5 second burning phase. All trajectory simulations for this rocket are based on the equations of motion as developed in [2]. Quadrant elevation (QE) angles of 200, 400, and 800 mils were analyzed. These resulted in nominal (no wind) impact ranges of 13.6, 23.0, and 33.0 kilometers, and apogees of 650, 2800, and 10200 meters, respectively.

The 155 millimeter howitzer projectile, HE, M107, Fuze, PD, M51A5, charge 5G, was selected as a representative artillery projectile. The same quadrant elevation angle cases as above were analyzed. These resulted in nominal impact ranges of 4.4, 7.5, and 11.0 kilometers, and peak altitudes of 240, 865, and 2800 meters, respectively.

All the simulations on this projectile are based on the equations of motion as developed in [3] with the appropriate modifications to include the Magnus force [4]. Corresponding results were obtained using the Ballistic Research Laboratory Modified Point Mass model [5] with the introduction of vertical winds.

The wind response characteristics of an unguided rocket and/or an artillery shell are usually displayed in the form of the wind weighting factors and the unit wind effects (i.e., magnitude of the vector difference a unit wind change causes on the impact point). The determination of the wind weighting factors, which are usually displayed in the form of a cumulative response curve, follows the procedure as defined in [6]. The wind weighting (ballistic) factor curve usually indicates the percentage of total wind displacement from a no-wind impact yielded by a constant wind to a given altitude and zero wind thereafter.

The vertical wind field can be induced either by thermal or mechanical means. Over a relatively flat terrain, vertical winds, resulting primarily from the convective heating of the Earth's surface, are relatively small in magnitude and tend to fluctuate in speed and direction with respect to both time and distance down range. The vertical winds, mechanically induced by a hill or an obstacle, seem to maintain their direction for longer durations of time and are usually greater in magnitude than thermally induced vertical winds.

THE HONEST JOHN (M50) TACTICAL ROCKET

A plot of the cumulative response curve for the Honest John (M50) tactical rocket with quadrant elevation angles of 200, 400, and 800 mils is shown in Figure 1. The cocking of the rocket into the wind during the burning phase and the subsequent drifting of the rocket with wind during the coasting phase cause the derivative of the response curve to go negative after burnout. It should be noted that most of the wind response occurs below 300 meters MSL.

The unit wind effects for the Honest John rocket are displayed in Table I. The vertical unit wind effect is a function of both the magnitude and direction of the vertical wind component. It should be noted that for an elevation angle of 200 mils, the vertical unit wind effect is four to five times larger than its horizontal counterpart. Thus it is quite possible for the vertical wind displacement of the rocket to be of the same magnitude as that caused by the horizontal component. In fact, for a QE of 200 mils, a range displacement of up to 300 meters can result from a reasonable vertical wind component, i.e., vertical wind speeds up to 2 miles per hour. It should be noted, however, that the M50 rocket is normally fired at higher QE's. The 300 meter displacement was derived from estimates of the vertical wind magnitude obtained at White Sands Missile Range, New Mexico [7]. This is significant since the one range probable error for 200 mils is 260 meters.

THE 155 MILLIMETER HOWITZER PROJECTILE

The 155 millimeter howitzer projectile, HD, M107, Fuze, PD, M51A5, charge 5G, has a muzzle velocity of 375 meters per second and a spin rate of 766 radians per second. This high spin rate is used for flight path stability. The maximum range of this projectile corresponds to an elevation angle near 800 mils. Thus, in general it is possible to achieve a desired impact range with either a high or low (more or less than 800 mils) elevation angle. A low QE angle is the usual mode of operation. High quadrant elevation angles are used for defilade fire to lob a projectile over a hill or some other obstacle, and are used sparingly.

TABLE I

TABULATION OF UNIT WIND EFFECTS

QUADRANT ELEVATION (MILS)		UNIT WIND EFFECTS (METERS/MPS)			
		CROSS	HEAD	TAIL	VERTICAL*
M50 ROCKET	200	62.4	61.3	60.6	276.5-332.6
	400	102.0	87.2	87.9	124.2-140.3
	800	185.7	108.5	105.1	7.4-19.7
155 HOWITZER	200	2.2	9.4	9.4	10.3-10.7
	400	5.4	21.5	21.5	14.8-15.2
	800	11.2	30.0	29.8	22.8-23.5

*The magnitude of the vertical unit wind effect is a function of both the direction (up or down) and the magnitude of the wind speed.

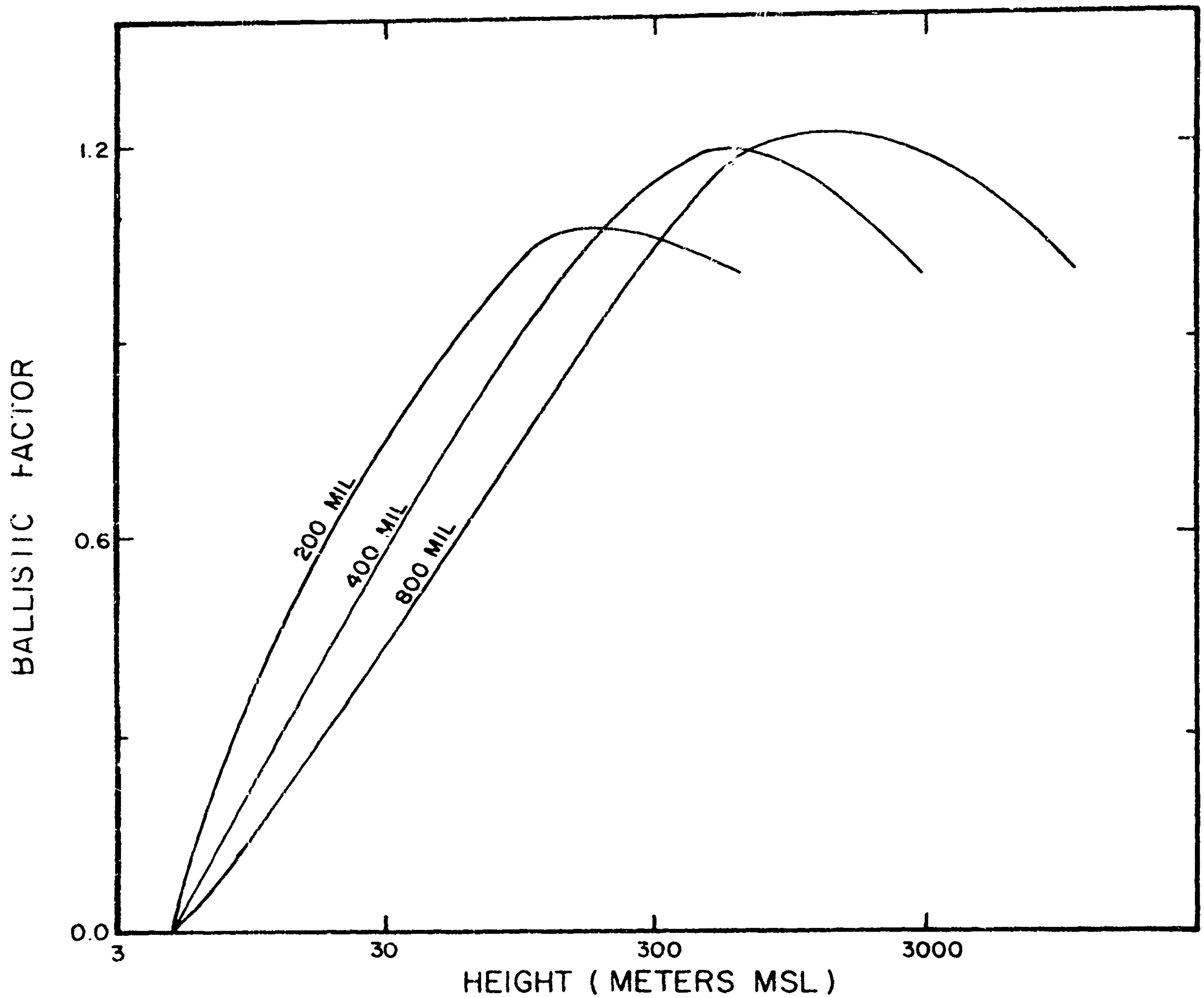

FIGURE I. HONEST JOHN BALLISTIC FACTOR CURVES

One should note from a plot of the cumulative response curve for the 155 howitzer (see Figure 2) that most of the wind response for the projectile occurs near the apogee of the trajectory.

The unit wind effects for the 155 howitzer are displayed in Table I. For each of the quadrant elevation angles, the magnitude of the vertical unit wind effect is approximately equal to that of the range component of the horizontal wind. Hence, for a low QE, good impact accuracy is generally possible even when neglecting any vertical wind compensated launcher setting. This is due to the relatively small magnitude of the vertical wind component in comparison to that of the horizontal component. However, during thunderstorm activity, large vertical wind currents can be present. If the projectile is to be lobbed over a hill or some obstacle where the vertical wind component can be as large as 20 meters per second [8], or if it is to be fired during thunderstorm activity, large impact errors can result from the neglect of the vertical wind component.

CONCLUSIONS

The vertical wind component plays a significant role on the impact point of both a M50 rocket fired at a low elevation angle and a 155 howitzer projectile fired at a high elevation angle, although this is not the usual mode of operation. Also during thunderstorm activities, the vertical wind effect on the 155 howitzer can and usually will be significant for any elevation angle. To obtain best accuracy for these cases, one must include launcher setting corrections to compensate for the vertical wind effects. At the present, no such compensation is made. Much should be done in this area. An analysis of the vertical wind field with respect to time and distance down range of the launch site, an estimate of the vertical wind the rocket is expected to encounter, and a method to implement the necessary corrections to the launcher settings are areas of possible research to help alleviate this problem.

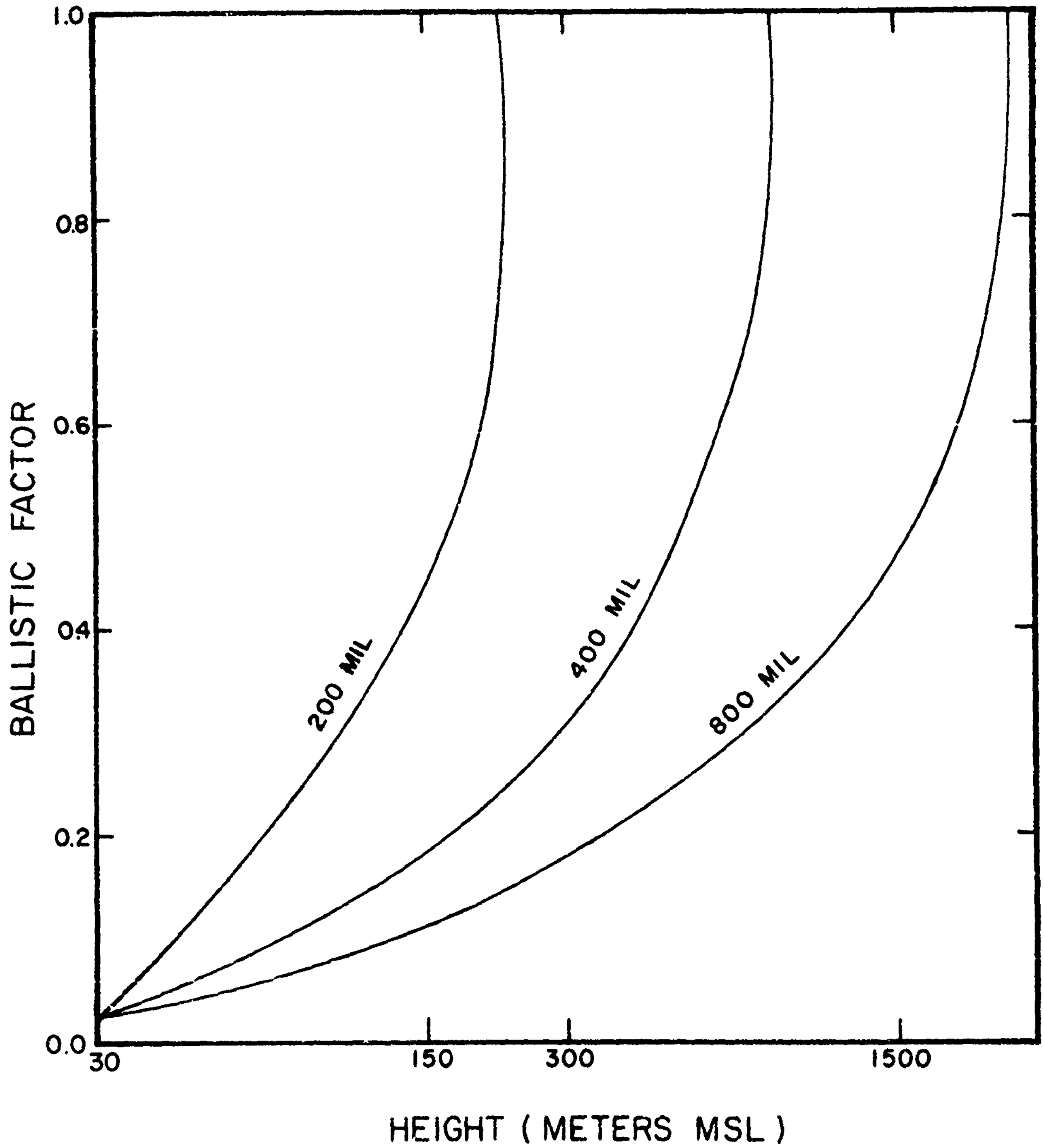

FIGURE 2. 155 HOWITZER BALLISTIC FACTOR CURVES

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